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Impacts of Spectral Shifts on Retrievals

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This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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Summary

- **There is a trend in spectral shift of AIRS channels.**
  - 0.63 parts per million in frequency per year (ppmf/year)
- **The trend in spectral shifts contributes to the observed trend in retrievals but is not the major cause.**
- **The impact of this spectral trend will be curtailed in v6, increasing the value of AIRS Level-2 and Level-3 products for climate studies.**

Variability of Spectral Shifts

- **See Denis Elliott's presentation**
- **Secular trend of ~0.63 parts per million in frequency (ppmf)**
  - Important for climate applications
- **Orbital cycle of ~3 ppmf peak-to-peak**
  - Peaks are at North & South Poles
  - Important for polar studies comparing poles
  - Effect will be small in tropical and mid-latitude regions
- **Seasonal cycle of ~2 ppmf peak-to-peak**
  - May eventually be important in studying seasonal climate effects
  - Much smaller than true seasonal signal and systematic seasonal unknowns

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Tests of Impact of Spectral Shifts on L2 Products

- **Results of "black box" tests on AIRS v5 IR-Only Level 2 PGE**
  - Alter the radiances to simulate the effect of uncompensated shifts in instrument frequencies.
  - Compare the resulting Level-2 products to those produced with nominal radiances.
  - Two shifted test sets:
    - Focus 3 (2002-09-06) granule 50 (night, ocean, tropical)
    - Simulated set from Hannon (49 clear global climatological profiles at 5 scan angles)

Caveats for Tests

- **The frequency set is shifted by a simple +/- 5 ppmf (parts per million in frequency).**
- **Shifting is done by a cubic spline, per module in radiance space.**
  - Tests should be repeated using simulated data from Strow and Hannon generated with a shifted forward model.
- **The simulated data used is cloud-free and noise-free.**
  - Checks with real data show similar results for clear and cloudy cases
- **A rough preliminary channel filling algorithm used in the test with real data.**
- **L2 retrieval is IR-Only.**
  - Trends are similar for IR-Only and IR-MW retrievals

Comparing Clear Tropical Cases, Simulated & Focus 3 Granule 50

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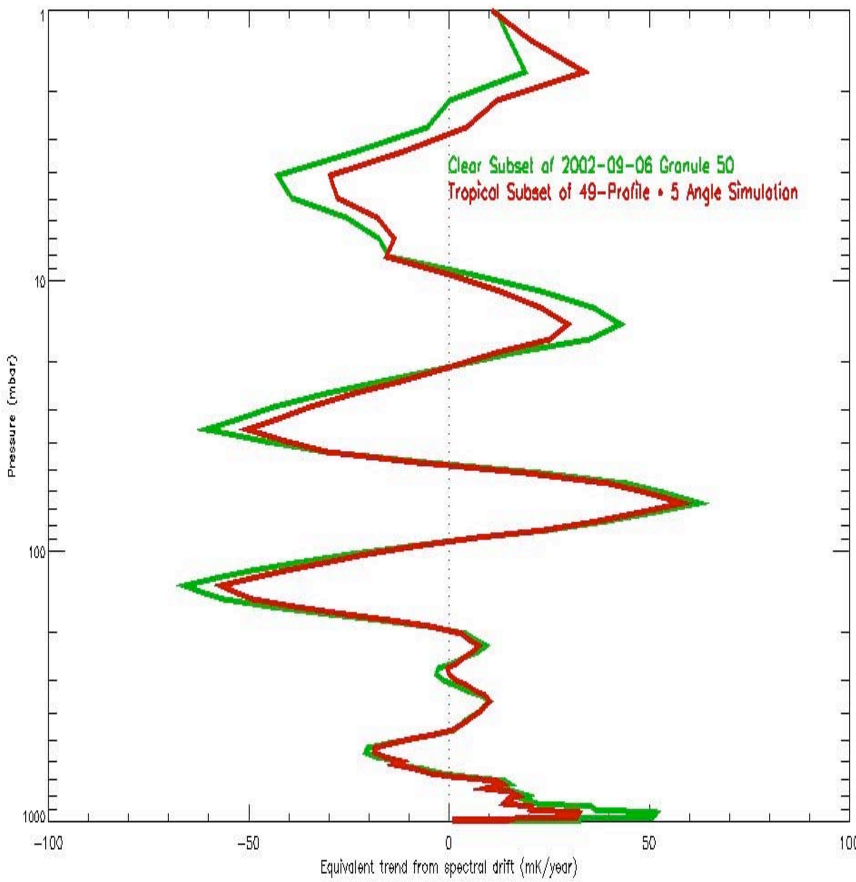
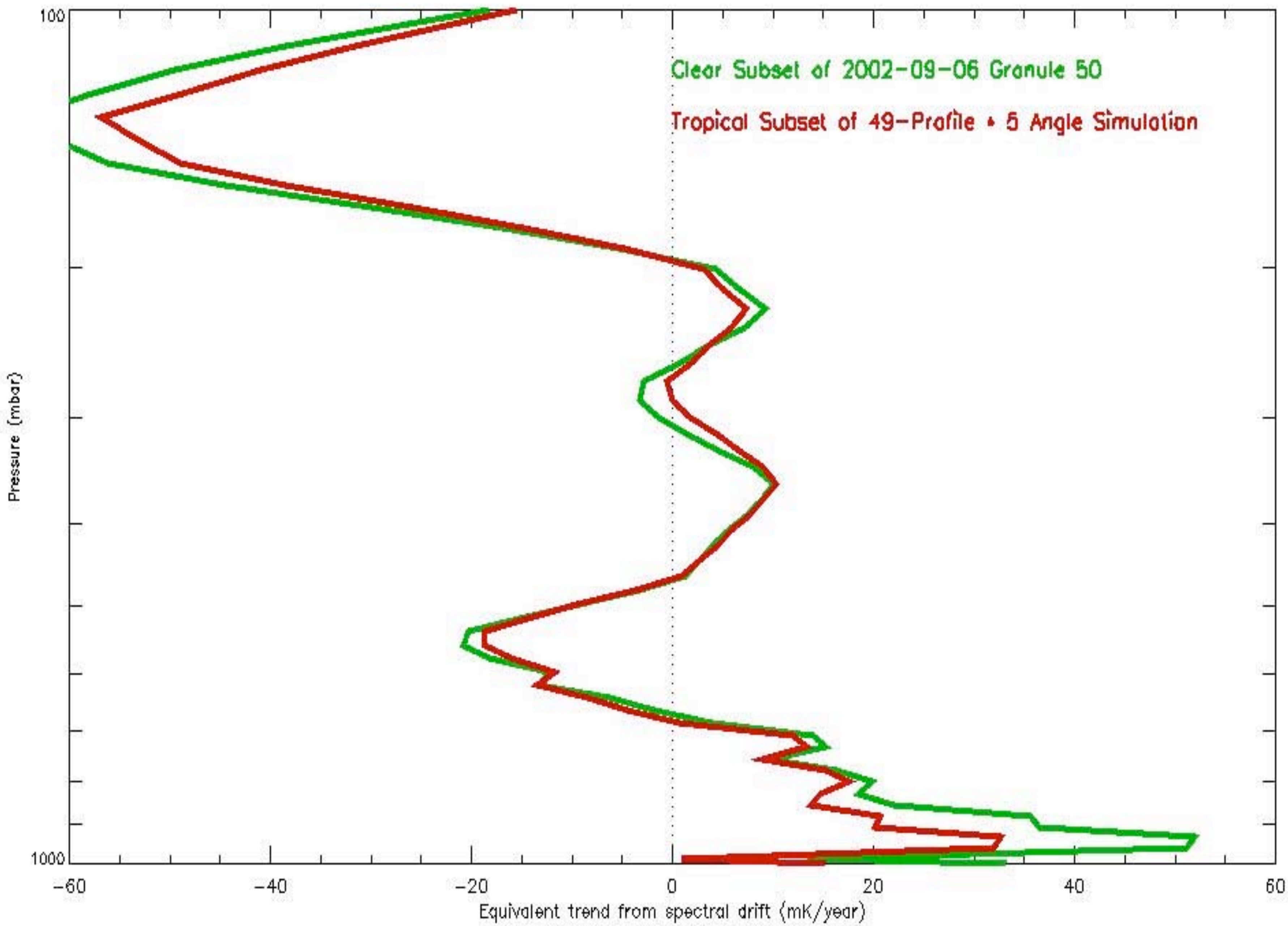
- **Trends are predicted from differences between AIRS v5 L2 products from radiances with and without shifting.**
  - Scaled to trend units assuming 0.63 ppmf/year
- **Results from the two tests agree very well.**
- **There's no overall bias.**
- **The largest peaks are ~55 mK/year at 35, 65, and 135 mbar.**
- **The observed shifts are smaller than the ~100 mK/year reported by Divakarla and Hearty, especially in the troposphere.**





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Impact of Modeled Spectral Shifts on Other Retrieved Parameters

From 2002-09-06 (cloudy nighttime) granule 50:

- **TSurfStd: +4.5 mK/ppmf; +3 mK/year**
- **TSurfAir: -100 mK/ppmf; -68 mK/year**
  - Much larger than change in TSurfStd
  - Opposite sign to TSurfStd
- **totH2OStd: -0.27 %/ppmf; -0.17 %/year**
- **CldFrcStd: -0.5 %/ppmf; -0.3 %/yr**

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Comparing to Trends in Real v5.0 Data

- **“Trends” in 100-layer profiles were calculated from IR/MW retrievals on the first 16 days of March, June, Sept, and December of 2002/3-2007/8**

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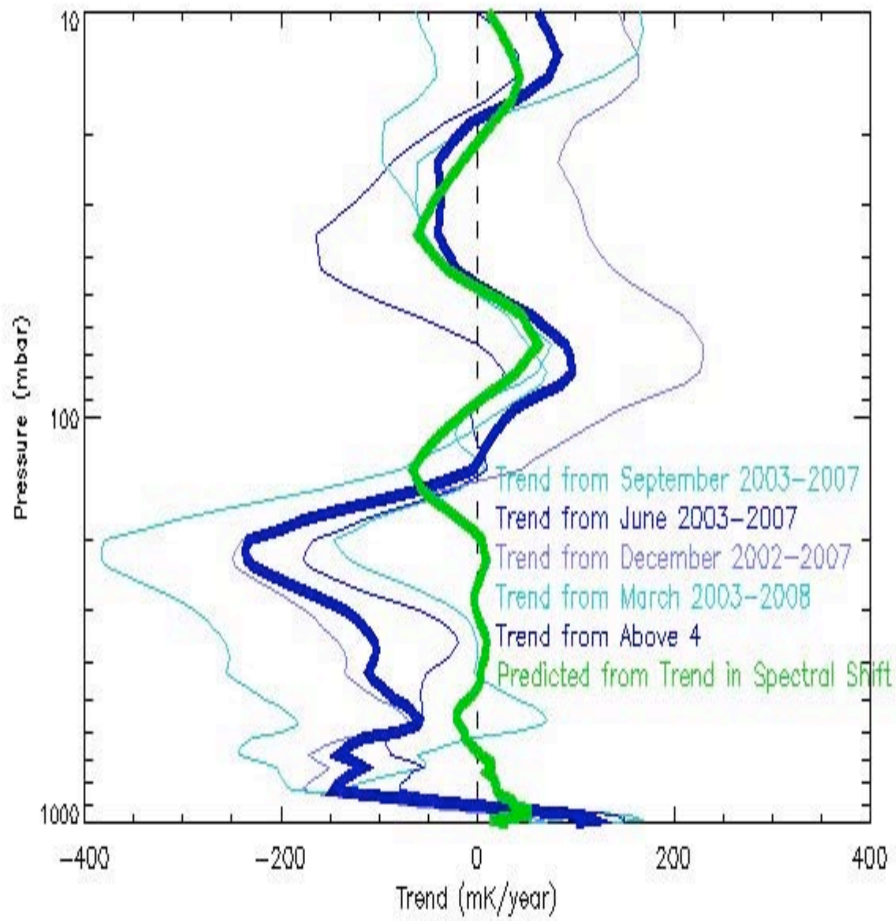
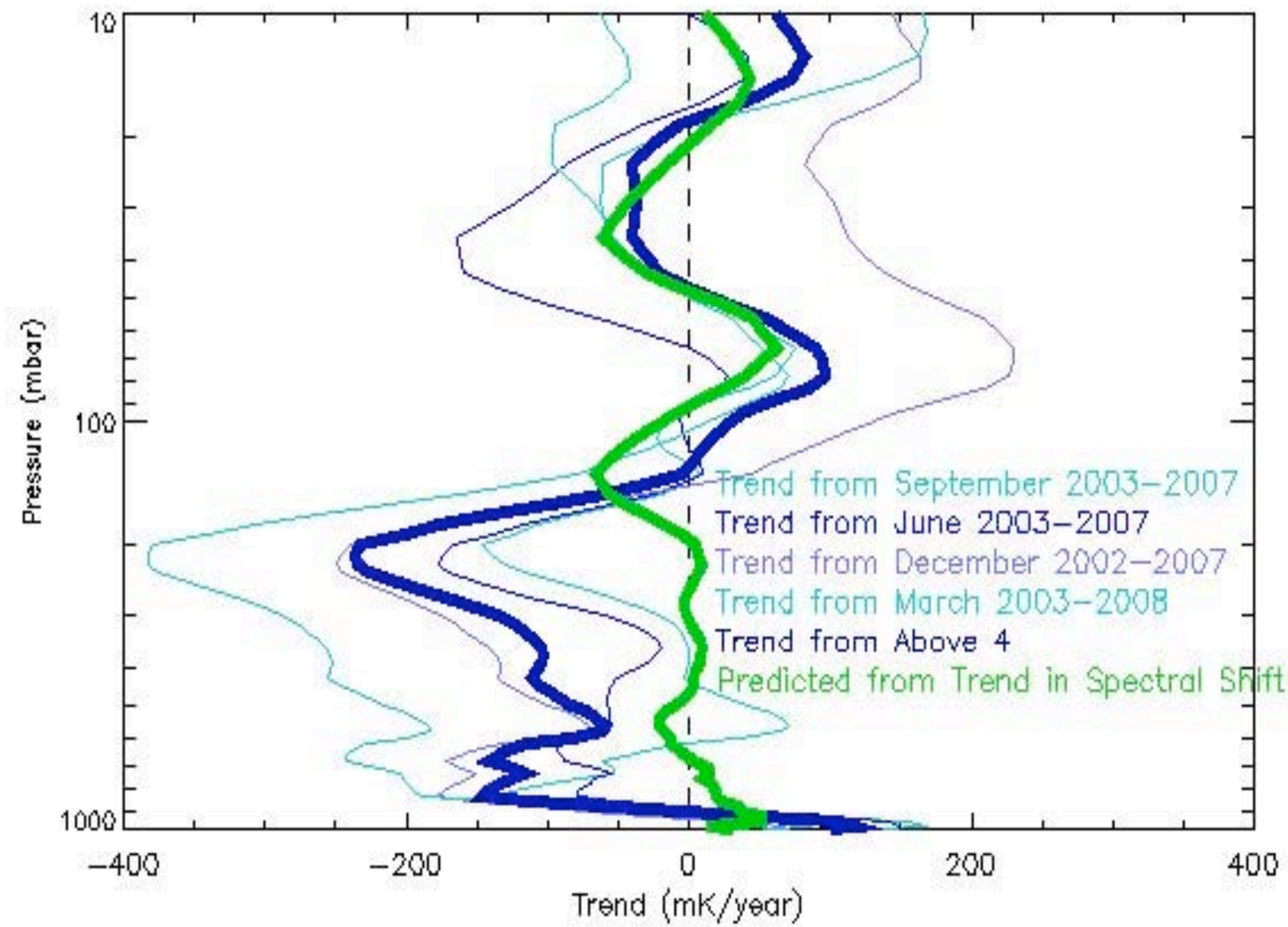
Comparing to Trends in Real v5.0 Data

- **The spectral shift accurately predicts the shape of the observed trend in the 10-100 mbar region**
- **The tropospheric shape and bias are something else:**
  - True trend
    - Climatology
    - 5-year El Nino timing
  - CO_2





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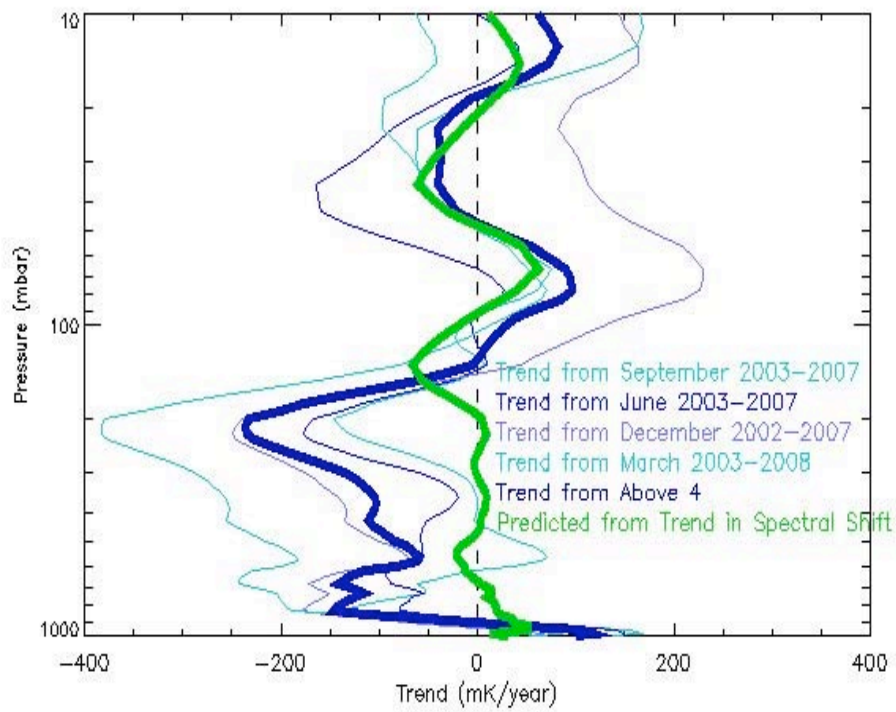
Tropical Trends in v5.0 Data Compared to Susskind

- **The heavy blue lines match!**
- **Based on different subsets of same v5 data**



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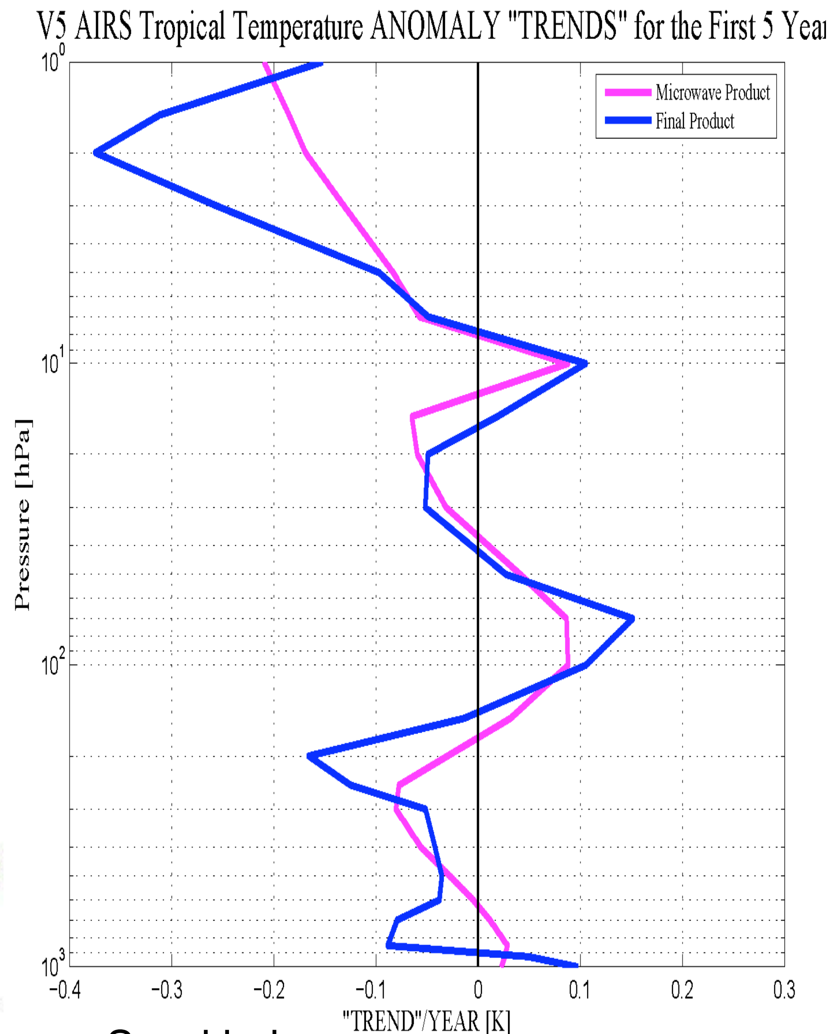

Susskind

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V6 Approach to Reducing the Impact of Spectral Shifts

- **Level-1B will accurately determine the instantaneous spectral shift**
  - See talk by Denis Elliott
- **Strow and Hannon will produce and Level-2 will use a radiance model which compensates for these shifts.**
  - This should eliminate all spectral shift effects in all **physical** retrieval steps.
- **The regression steps need further study. Some possibilities:**
  - Reduce the use of regressions in the retrieval.
  - Adjust the radiance data to the static frequency set (i.e. apply the Level-1C algorithm) before passing the data to regressions.
  - Train the regressions on a data set that represents the full range of shifts to be encountered.
  - Remove the channels with the most impact from spectral shifting from the regression input set.

Summary

- **There is a trend in spectral shift of AIRS channels.**
  - 0.63 parts per million in frequency per year (ppmf/year)
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- **The impact of this spectral trend will be curtailed in v6, increasing the value of AIRS Level-2 and Level-3 products for climate studies.**

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Backup Materials

- **Background figures of observed trend in AIRS Level-2 products**
- **Per-module analysis of the effect of spectral shifting**
- **The effect of spectral shifts on regression PC scores**

From Divakarla -- Apparent Trend in AIRS v4 vs. Radiosonde

- **Divakarla et al 2006**
- **AIRS version 4**
- **Apparently correlated with CO_2**
- **AIRS version 5 added changing CO_2 background in physical retrieval, but trends persist**

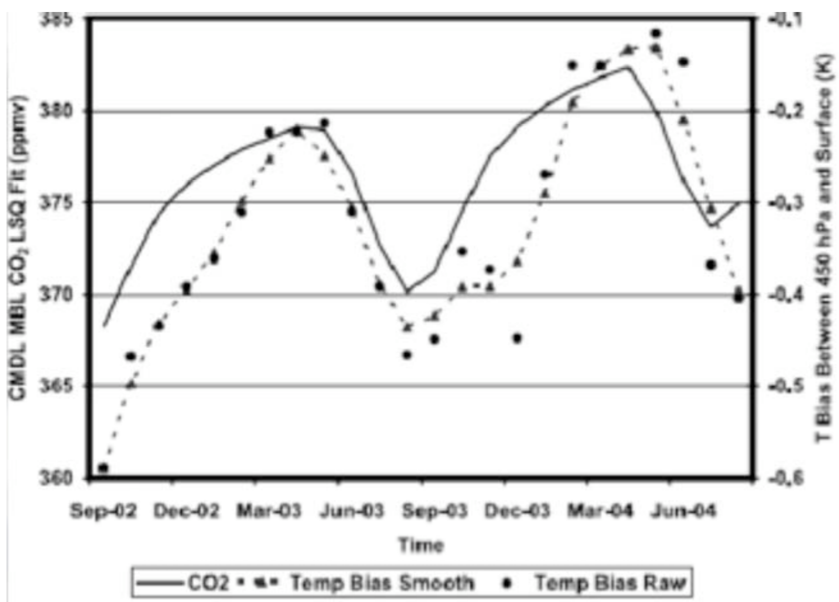

Figure 14. Seasonal trends between AIRS retrieval bias 450 hPa to surface and CMDL MBL CO_2, 90°N–90°S. Average differences between RAOB and AIRS temperatures are indicated by solid circles, smoothed differences using a 2-month sliding boxcar average are indicated by the dashed line, and zonally weighted linear least squares fit for the CMDL MBL product are indicated by the solid line.

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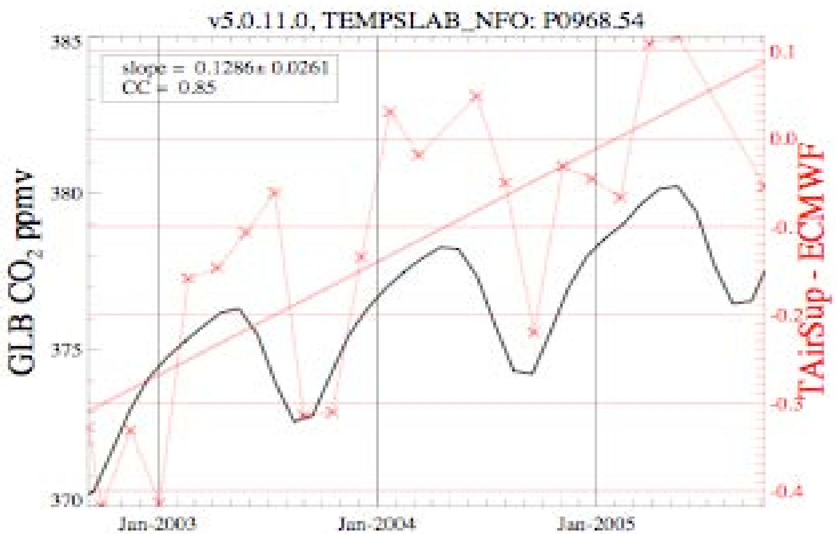
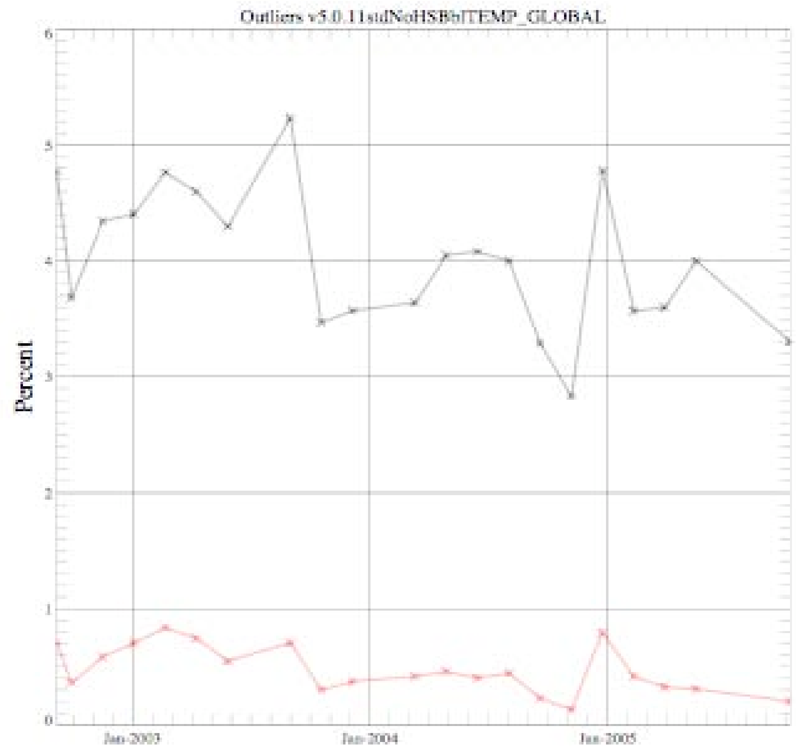
From Hearty - Trend in V5 Global Temperature

- **Upward trend in temperature bias vs. ECMWF**
- **Downward trend in outliers**





Much more in Hearty presentation in http://airs.jpl.nasa.gov/Science/ResearcherResources/MeetingArchives/TeamMeeting20070327/

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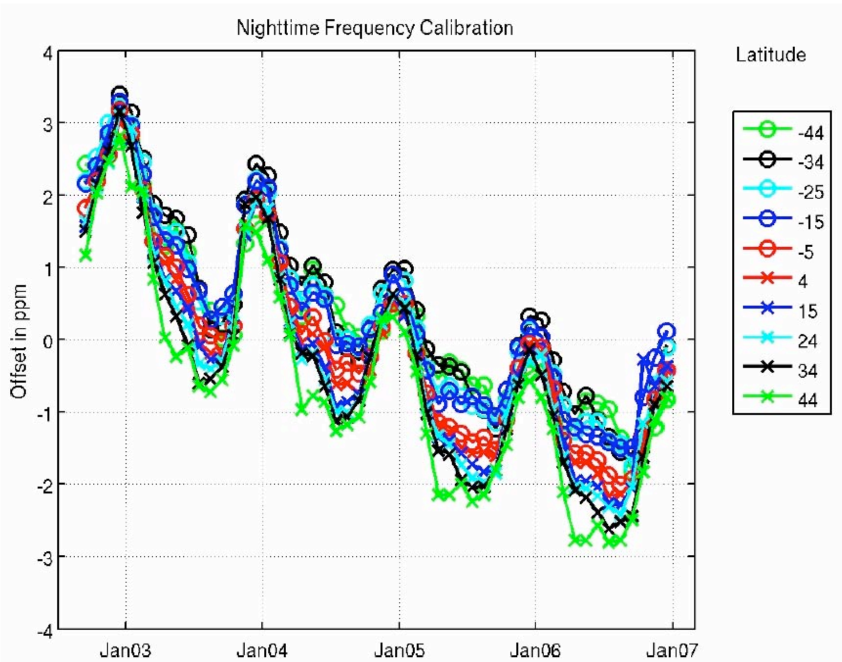
There is a Seasonal Cycle + Drift in Frequency



Strow & Hannon

The variation of the SRF centroid with season and latitude. The seasonal variation has a p-p amplitude of about 3 ppmf. The trend in the SRF centroid between 2002 and 2007 has been -0.63 ppmf/year. Superimposed on this trend is a combination of orbital and seasonal variability. The orbital variability shows up as a change of the SRF centroid with latitude. Note the peaks in December of every year.

Aumann

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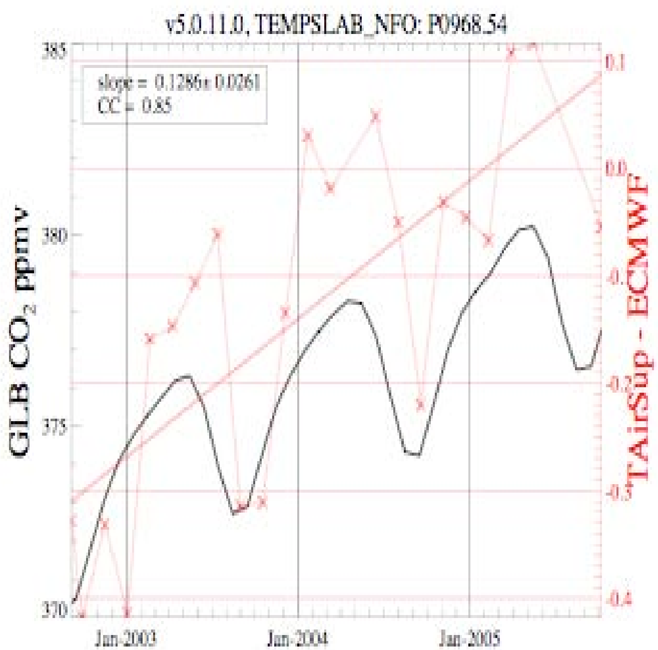
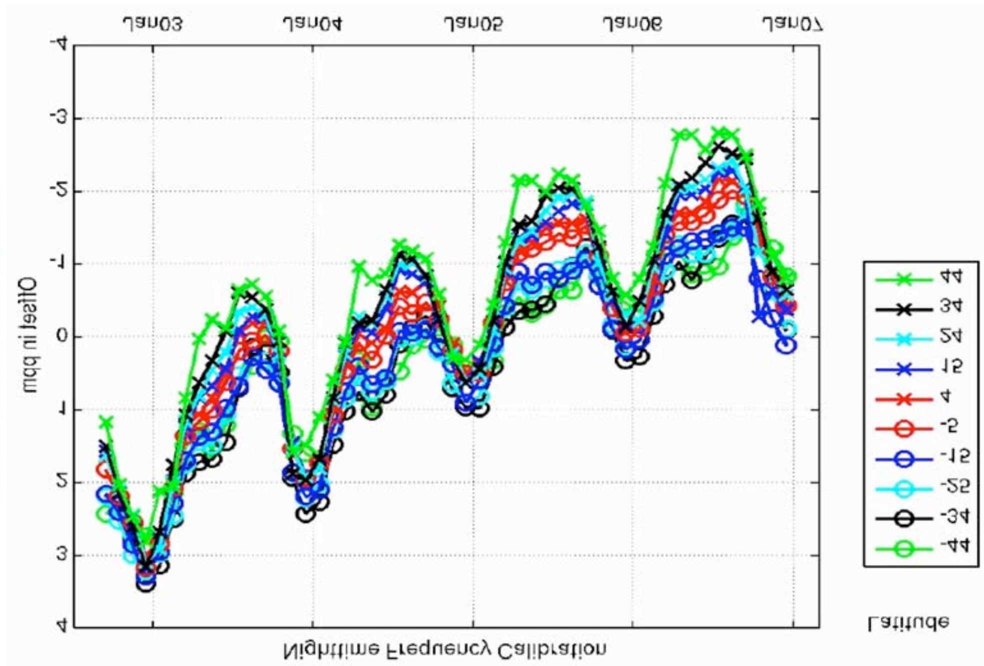
Could These Be Related?



Hearty



Strow & Hannon

- **Ratio of size of cycle to secular term is similar**
- **Timing of peaks is different**
  - March & September for retrieval differences
  - December & August for spectral shifts

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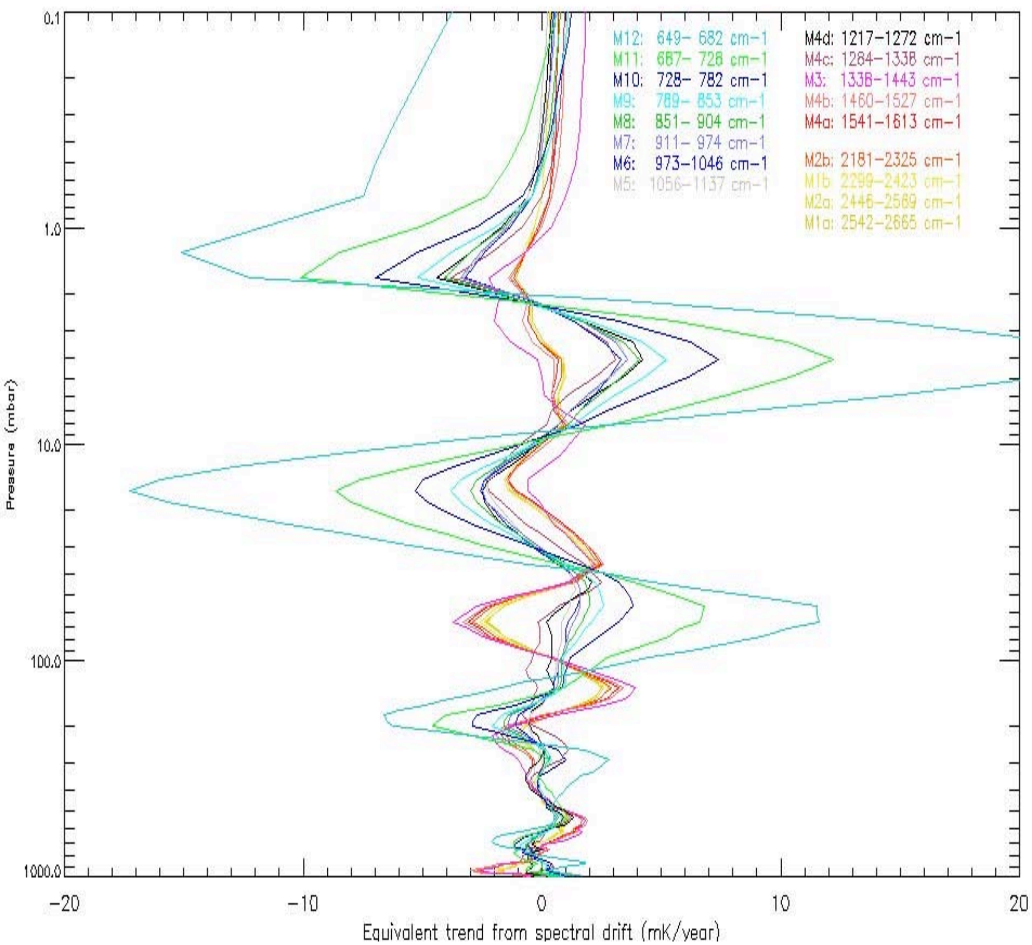
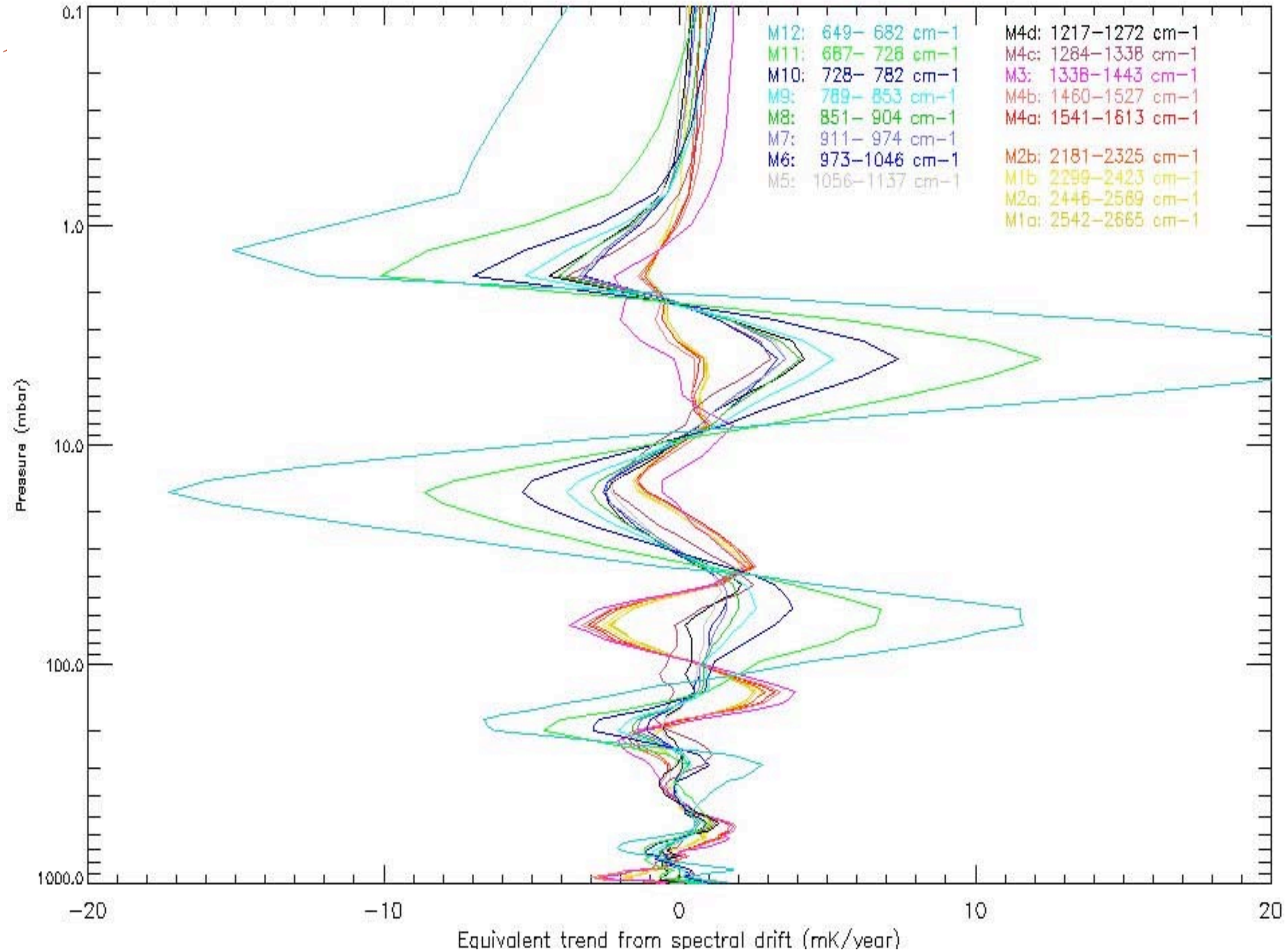
Temperature Profile Impacts per Module



- **Strongest impacts are in longwave M12, M11, M10, all above 100 mbar**
- **M3 & M4 become important in the boundary layer**



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Impact of Spectral Shifts on Other Retrieved Parameters by Module

- **TSurfStd: -4.5 mK/ppmf; -/+3 mK/year**
  - M4d (1217-1272 cm-1), M3 (1338-1443 cm-1) are biggest contributors
- **TSurfAir: +100 mK/ppmf; +/-68 mK/year**
  - M4b (1460-1527 cm-1), M3 (1338-1443 cm-1) are biggest contributors
  - Much larger than change in TSurfStd
  - Opposite sign to TSurfStd
- **totH2OStd: +0.27 %/ppmf; +/-0.17 %/year**
  - M3 (1338-1443 cm-1), M4c (1284-1338 cm-1), M4d (1217-1272 cm-1) are biggest contributors

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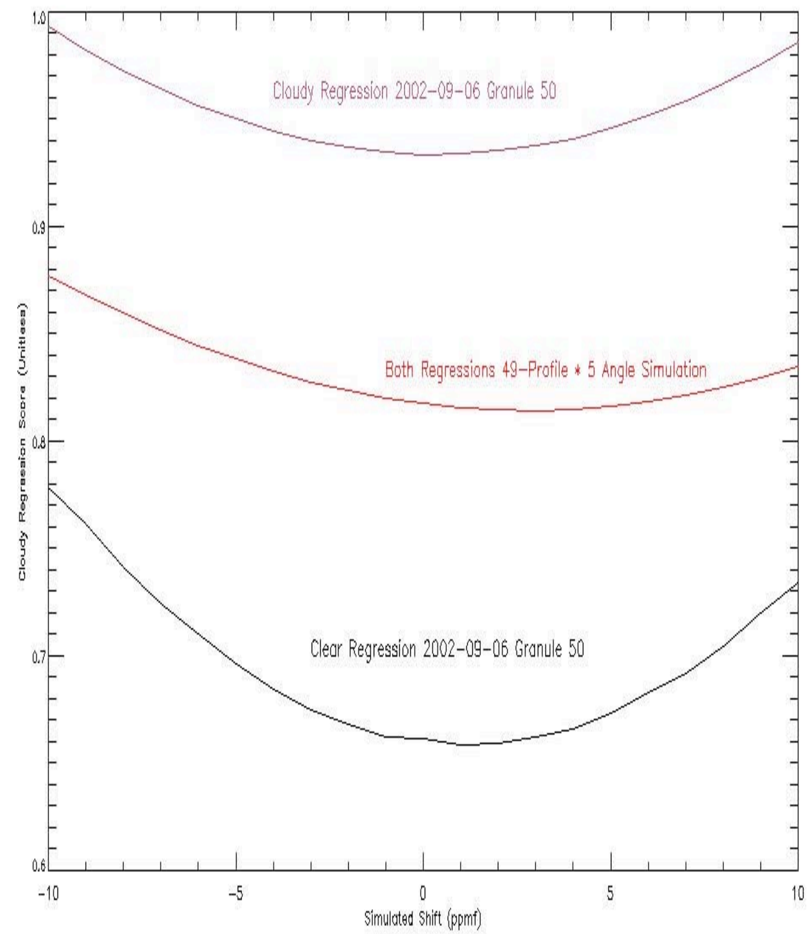
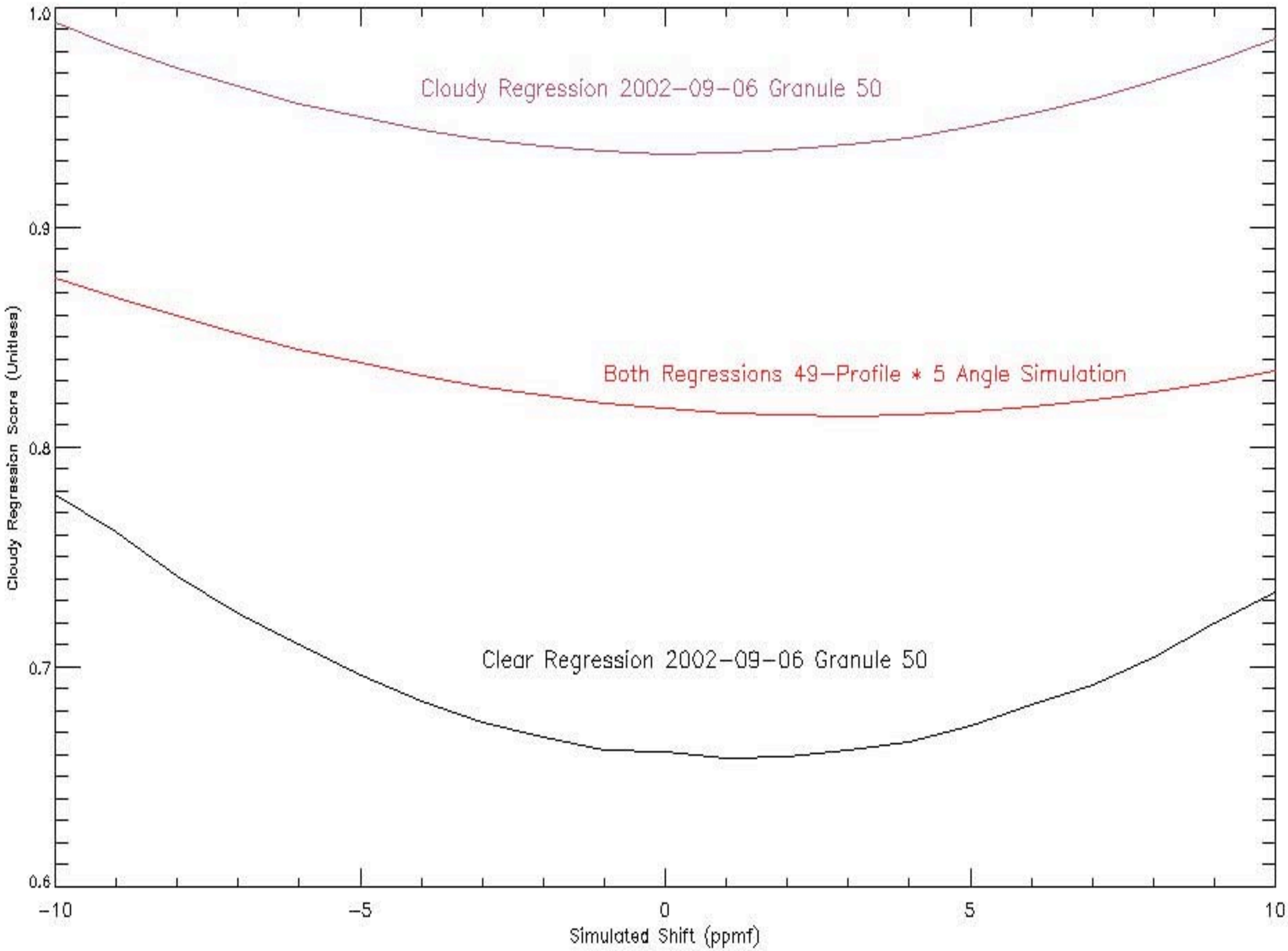
Regression Scores vs. Simulated Spectral Shift

- **Maroon: Cloudy regression PC score from real 2002-09-06 granule 50**
  - Best score at zero shift
- **Red: Clear and Cloudy PC scores from simulated clear data**
  - Best score at a shift of +3ppmf
- **Black: Clear PC score from real 2002-09-06 granule 50**
  - Best score at 1 ppmf shift
  - Not a perfect parabola
  - Steeper





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Discussion of PC Scores

- **Shallow parabolas are best. They indicate that little damage is done to retrievals by feeding in data shifted differently from the training set.**
- **Shift of minimum may indicate a difference between test data and mean of training set of ~3 ppmf:**
  - 3 ppmf ~= 5 years of secular trend
  - 3 ppmf ~= seasonal peak-to-peak variation
  - 3 ppmf ~= 1/2 of day-night peak-to-peak variation
    - Real data used is a tropical night granule
- **The compound shape of the curve for clear PC score on real data may be combination of one parabola centered on 3 ppmf from training effect plus another centered on 0 shift from a filling effect. Shifting by cubic splines is sensitive to values in neighboring channels, and bad channels in real data must be filled before spline interpolation.**
- **Or maybe multiple parabolas from disjoint training subsets?**